Available online at www.sciencedirect.com
ScienceDirect
Geochimica et Cosmochimica Acta 71 (2007) 3904–3914
Geochimica et Cosmochimica Acta
www.elsevier.com/locate/gca

Nd and Sr isotopic characteristics of Chinese deserts: Implications for the provenances of Asian dust

Jun Chen [a,*], Gaojun Li [a], Jiedong Yang [a], Wenbo Rao [a], Huayu Lu [b], William Balsam [c], Youbin Sun [a], Junfeng Ji [a]

[a] State Lab of Mineral Deposits Research, Institute of Surficial Geochemistry, Department of Earth Sciences, Nanjing University, Nanjing 210093, China
[b] School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210093, China
[c] Department of Earth and Environmental Sciences, University of Texas at Arlington, Arlington, TX 76019, USA

Received 18 October 2006; accepted in revised form 25 April 2007; available online 29 May 2007

Abstract

Silicate Nd–Sr isotopes of the fine-grained fractions of the 10 major deserts and sandy lands in North China and the loess in Chinese Loess Plateau were systematically investigated. Wide ranges in Nd–Sr isotopic compositions have been observed. The results of the <75 μm silicate fractions show that the Nd–Sr isotopic compositions of each desert are quite homogeneous and unique. According to the geographic distribution of the deserts and their Nd–Sr isotopes of both the <75 and <5 μm silicate fractions, three isotopic regions of Chinese deserts can be identified: (A) the deserts on the northern boundary of China, with the highest $\varepsilon_{Nd}(0) > -7.0$; (B) the deserts on the northern margin of Tibetan Plateau, with $\varepsilon_{Nd}(0)$ ranging from −11.9 to −7.4; and (C) the deserts on the Ordos Plateau, with the lowest $\varepsilon_{Nd}(0) < -11.5$. The distribution of the threes isotopic regions is controlled by the tectonic setting in North China, which implies that the materials of the deserts are derived from the locally eroded rocks from the surrounding mountains and the Nd–Sr isotopic signatures of these deserts could be quit stable over the past million years on the sub-tectonic time scales if there is any desert at those times. The Nd–Sr isotopic compositions of the loess are mostly close to those of the deserts in isotopic region B, suggesting that the main source regions of the last glacial loess in the Chinese Loess Plateau are Badain Jaran Desert, Tengger Desert, and Qaidam Desert. Also, the comparison between the Nd–Sr isotopes of the <5 μm silicate fractions of the deserts and the ancient dust falls in the North Pacific and Greenland show that the Asian end members of these dust falls are derived most from the deserts in the isotopic region B and less from those in the isotopic region C.

1. INTRODUCTION

Wind-blown mineral dust, once uplifted into the atmosphere, has broad environmental impacts as it is spreading all over the world, e.g., modulating atmospheric CO_2 concentration primarily by influencing oceanic productivity (e.g., Andreae, 1996), removing, depositing and transporting of atmospheric pollutants (Sievering et al., 1989; Winchester and Wang, 1989; Inoue et al., 1991; Carmichael et al., 1996; Dentener et al., 1996), affecting climate directly through scattering, transmission and absorption of solar radiation, and indirectly by acting as nucleus of cloud nucleation when coated with soluble material (Andreae, 1995; Levin et al., 1996; Tegen et al., 1997; Sokolik et al., 2001), controlling nutrient supply in some terrestrial ecosystems (Chadwick et al., 1999), and impacting the chemical composition of seawater (e.g., Jacobson, 2004; Ling et al., 2005). Beside these, the health problems caused by the heavy dust falls have become an increasing concern in recent years (Wilkening et al., 2000; Sun et al., 2001).

* Corresponding author. Fax: +86 25 83592393.
E-mail addresses: chenjun@nju.edu.cn (J. Chen), ligaojun@nju.org.cn (G. Li), jdyang@nju.edu.cn (J. Yang).

0016-7037/$ - see front matter
doi:10.1016/j.gca.2007.04.033

Long-range transports of Asian dust have been identified in China (e.g., Liu, 1985; Ding et al., 2001), Korea and Japan (Kanayama et al., 2002a,b; Mori et al., 2002), North Pacific Ocean (Nakai et al., 1993; Pettke et al., 2000), western America (Wilkening et al., 2000), Greenland (Biscaye et al., 1997; Svensson et al., 2000; Bory et al., 2002, 2003), and Europe (Grousset et al., 2003). The Ancient dust deposits in these regions, for example, the loess–paleosol sequences in Chinese Loess Plateau, provide archives to trace the atmospheric circulation pattern, as well as paleoclimate change (An et al., 1991; Chen et al., 1999, 2006; Ding et al., 2001; Guo et al., 2002; Li et al., 2007). Mineral dust particles are highly heterogeneous, but are commonly treated as a relatively homogeneous group, and this may lead to increasing uncertainties in the atmospheric chemistry and climate models (Buseck and Pósfai, 1999), and misleading the interpretation of the environmental proxies archived in dust deposits, since evidences show that the dusts originated from different source regions have different physicochemical properties (e.g., Zhang et al., 1993, 1997). Therefore, the knowledge on the source regions of Asian dust and their temporal variations is essential and critical for understanding the paleo-environmental records in the dust deposit as well as for predicting the overall ecological impacts of the dust.

Previous studies suggested that the deserts, Gobi deserts and sandy lands in the arid North China and their surrounding regions are all the potential source areas of Asian dust (Liu et al., 1994; Zhang et al., 1997; Derbyshire et al., 1998; Sun, 2002; Fang et al., 2004; Rao et al., 2006). However, the detailed source regions and their spatial and temporal variations are poorly understood, despite an increasing number of studies. It is much easier to monitor the source of modern dust with the helps of instrumental observations. Satellite imagery and the calculation of airmass back trajectories have been used frequently to trace the dusts back to their source areas (e.g., Shao and Dong, 2006). However, for the ancient dust deposits, geochemical tracers provide the most powerful tools (Nakai et al., 1993; Biscaye et al., 1997; Grousset et al., 2003).

The radiogenic neodymium and strontium isotopes are generally considered to be reliable indicators for the provenance of sediments not only because geologic bodies have different Nd–Sr isotopic compositions depend on their origins and ages but also because the Nd–Sr isotopes have limited alternations during the surficial processes such as weathering and transportation (Goldstein et al., 1984; Goldstein and Jacobsen, 1988; Grousset et al., 1988; Revel et al., 1996; Grousset and Biscaye, 2005). The Nd–Sr isotopic signatures of the deposits of Asian dust have been investigated over the Northern Hemisphere, including those in Chinese Loess Plateau (Gallet et al., 1996; Jahn et al., 2001), North Pacific (e.g. Asahara et al., 1999; Pettke et al., 2000), Greenland (e.g., Biscaye et al., 1997), and Europe (Grousset et al., 2003). Yet it took a long time to accept that the deserts, Gobi and sandy lands in northern and northwestern China are the provenances of Asian dusts, the questions on which regions are the main sources are ambiguous. Tracing the dusts back to their source regions requires detailed and systematic investigations on the Nd–Sr isotopic compositions of all Chinese deserts as potential dust sources. However, only sparse investigations have been published (Liu et al., 1994; Biscaye et al., 1997; Sun, 2002; Honda et al., 2004; Nakano et al., 2004; Yokoo et al., 2004; Kanayama et al., 2005; Rao et al., 2006). According to these investigations and those of Gallet et al. (1996), Yang et al. (2000, 2001), and Jahn et al. (2001) for loess, the following points can be summed up: (1) the Nd isotopic compositions of the desert sand and eolian deposits have little alternation during the processes of weathering, transportation (mineral sorting) and deposition, suggesting Nd can be served as an robust provenance indictor while the Sr isotopic composition is strongly affected by these processes, and therefore provides less information about the provenance than desired; (2) Sr isotopic composition can be used as excellent provenance monitor only when the samples are carefully pretreated, e.g., selecting suitable grain-size fractions to eliminate the influence of mineral sorting and using the silicate fraction through weak-acid leaching to excluding the influence of calcite dissolution during the weathering/or pedogenesis; (3) the limited pioneering studies indicate that the Nd–Sr isotopic ratios of the Chinese deserts vary spatially thereby validating the application of Nd–Sr isotopic ratios to trace the dust back to their sources in the different deserts.

To summarize, there are separated investigations on the Nd–Sr isotopes of the Chinese deserts and sandy lands, but a complete investigation on all the deserts and sandy lands has not been carried out yet. This would weaken the previous conclusions which relate the Chinese deserts and sandy lands to the loess deposit in Chinese Loess Plateau as well as the eolian deposit beyond. This study systematically investigates the Nd–Sr isotopic compositions of the surface sand in the Chinese 10 major deserts and sandy lands and the loess on the Chinese Loess Plateau, aims to provide better constrains on the source regions of Chinese loess and the ancient dust falls in Japan, North Pacific region, and even in Greenland.

2. MATERIALS AND METHODS

2.1. Materials and settings

The Chinese deserts and sandy lands are distributed along 600 km of longitude and 4000 km of latitude in North China with an area up to 1.50×10^6 km^2 (Zhu et al., 1980). Due to the extremely arid climate and the spare/bare vegetation cover, most of the sand in the deserts and sandy lands are migrating and 10^8–10^9 tons of sand particles are deflated, transported, and deposited in the northern China and beyond every year (Zhang et al., 1997; Wang et al., 2005). In the present study, samples of surface sand (within the upper 30 cm) were collected from the 10 major Chinese deserts and sandy lands as potential sources for Asian dust and for the loess in Chinese Loess Plateau (Fig. 1). The sampled deserts and sandy lands include the Taklimakan Desert in Tarim basin, the Gurbantunggut Desert in Junggar basin, the Qaidam Desert in Qaidam basin, the Badain Jaran Desert and Tengger Desert in Alashan Plateau, the Hobq Desert and Mu Us Desert in